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Declaration
of Robinson
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IN RE APPLICATION OF: Braddock Examiner: KANG

SERIAL NO: 09/636,484 GROUP ART UNIT: 2811

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TITLE: INTEGRATED TRANSISTOR DEVICES

TO: ASSISTANT COMMISSIONER OF PATENTS

SECOND 37 CFR 1.132 DECLARATION OF DAVID BRADDOCK

I am the inventor, David Braddock:

Passlack's Ga₂O₃ is not insulating and the structure of layers above Passlack's GaAs substrate could not be grown on Kikkawa's InP substrate. These facts are inconsistent with the obviousness conclusions reached by the examiner.

Kikkawa does not teach equivalency of InP and GaAs substrates.

1. There is no AlGaAs composition for which lattice matching exists with InP. Therefore, AlGaAs can not be grown epitaxially on InP. These facts are well known in the art in prior to 1997. The lattice constants of InP and AlGaAs, at any composition of AlGaAs, are so far apart that epitaxially growth of the AlGaAs in InP is impossible. Therefore, AlGaAs can not be grown epitaxially on InP. These facts are well known in the art. Non-epitaxially grown AlGaAs on InP has no device potential and therefore no utility of which I is aware.

2. Even for a composition of In_xGa_{1-x}P containing as low as one percent GaP, In_xGa_{1-x}P does not lattice match to an InP substrate. Therefore, InGaP cannot be grown epitaxially on InP with low defect densities. These facts were well known in the art in 1997. Compositions of less than one percent GaP in In_xGa_{1-x}P, wherein lattice matching may be possible, on InP, have no device potential and therefore no utility of which I is aware. InGaP grown non-epitaxially on InP has no device potential and therefore no utility of which I is aware. Therefore, In_xGa_{1-x}P on InP has no utility of which I is aware.

3. The applied Passlack patent teaches using only AlGaAs or InGaP lattice matched to GaAs. The applied Passlack patent does not mention InP substrates. I presume that Passlack's failure to mention InP substrates is at least because Dr. Passlack knew that his AlGaAs and InGaP devices grown on an InP substrate would not grow epitaxially on InP and therefore could not produce a useful device.

3a. In a telephone conference with my counsel Dr. Neifeld on April 18, 2003, I reviewed the office action and the outstanding rejections against this application. During that review I recognized that claim 36, as amended, claimed some inoperative embodiments, in that claim 36 claimed alternatives of an AlGaAs heterostructure or an InGaP heterostructure grown on InP. Please note that my specification for this application, in the summary of the invention section, did not contain that error. Instead, it stated the following for the InP substrate inventions:

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In another preferred embodiment, the compound semiconductor heterostructure comprises an $\text{In}_y\text{Ga}_{1-y}\text{As}$, $\text{Al}_x\text{In}_{1-x}\text{As}$, and InP compound semiconductor heterostructure and n-type and/or p-type charge supplying layers which are grown on an InP substrate, and a refractory metal gate of W, WN, or WSi, self aligned donor (n-channel FET) or acceptor (p-channel FET) implants, and source and drain ohmic contacts.

That passage defines $\text{Al}_x\text{In}_{1-x}\text{As}$, not $\text{Al}_x\text{Ga}_{1-x}\text{As}$, as an alternative composition of the heterostructure on an InP substrate. That passage does not define InGaP as an alternative composition of the heterostructure on an InP substrate.

4. It is now known that stoichiometric Ga_2O_3 is an *n type semiconductor*, not an insulator. It has room temperature residual n type conductivity on the order of 10^{16} per cubic centimeter. That conductivity is much larger than the conductivity of insulating materials used as gate insulators. Materials used as gate insulators generally have conductivities of *less than* 10^{12} per cubic centimeter. Accordingly, stoichiometric Ga_2O_3 , which is what the Passlack patent teaches, is not useful for performing the function of a gate insulator.

5. At the time Passlack filed for his patent, he did not know that stoichiometric Ga_2O_3 had a relatively large residual conductivity. I speculate that Passlack filed for the Passlack patent assuming that residual conductivity of Ga_2O_3 was caused by defects, vacancies, or impurities and therefore he thought that conductivity could potentially be reduced to a level at which his Ga_2O_3 would be commercially useful as a gate insulator.

5a. At the time Passlack filed for the applied Passlack patent, I believe that Passlack did not know that stoichiometric Ga_2O_3 had a relatively large residual conductivity. I speculate that Passlack filed for the Passlack patent assuming that residual conductivity of Ga_2O_3 was caused by defects, vacancies, or impurities and therefore Passlack thought that conductivity could potentially be reduced to a level at which his Ga_2O_3 would be commercially useful as a gate insulator.

5b. Dr. Passlack has recently first authored a book chapter regarding Gallium Oxide on GaAs, co-authored with me and others.¹ In that chapter, Dr. Passlack admits that, even though stoichiometry of Ga_2O_3 can be maintained, Ga_2O_3 's inherently conductive nature cannot be eliminated. Dr. Passlack's own book chapter discusses that conductivity of Ga_2O_3 is as high as 10^{18} , and that the specific resistivity is always low relative to an insulator. See section 4.3, page 347. Moreover, Passlack also has another patent, 6,094,295, wherein he identified Ga_2O_3 as a UV transparent conducting material.² For example, see the abstract of 6,094,295. Thus, the implication that the examiner draws from the applied Passlack patent, which is that Ga_2O_3 can form an insulating layer, and therefore that it can form a gate insulating layer, is clearly incorrect.

6. Moreover, the devices disclosed in the Passlack patent are not commercially useful and have no practical utility. Ga_2O_3 does have a relatively large conductivity. The

¹Chapter 12 entitled "Gallium Oxide on Gallium Arsenide: Atomic Structure, Materials, and Devices", is attachment 1. For publication in "Gallium Oxide on Gallium Arsenide: Atomic Structure, Materials, and Devices" in III-V Semiconductor Heterostructures: Physics and Devices, edited by W.Z. Cai, Transworld Research Publisher, Kerala, India (2003).

²A copy of 6,094,295 to Passlack is attachment 2.

Passlack device is not commercially useful and would not have any practical utility. I state this because the Ga₂O₃ oxide leaks just as badly or worse than a standard compound semiconductor HEMT (or PHEMT) that utilizes gate metal directly on top of an AlGaAs top layer. The metal on the AlGaAs layer forms a Schottky-barrier to current flow at the gate of the transistor. In the case of Passlack, the Ga₂O₃ can be so highly conducting (e.g. 10E18cm⁻³ conductivity) that the gate metal on Passlack's MOSFETs will form Ohmic contacts at the gate (and thus have huge gate leakage). Thus, Passlack's MOSFET devices that utilize Ga₂O₃-on-GaAs would have no practical utility over the prior art (i.e. standard HEMTs and PHEMTs) over which Passlack has obtained a patent.

7. The Passlack patent does not disclose a gate insulator. Instead, the Passlack patent discloses:

The FET includes a *stoichiometric Ga₂O₃ gate oxide layer* positioned on upper surface of a compound semiconductor wafer structure. [Col. 2 lines 45-47; emphasis supplied.]

8. There is no motivation in the art to substitute InP for the substrate used by Passlack, for two reasons. First, there is no specific teaching or suggestion of such a modification of Passlack's teachings. Second, it is well known that such a substitution would prevent epitaxial growth of either one of the AlGaAs and InGaP materials that the applied Passlack patent discloses are epitaxially grown on a GaAs substrate.

8a. The lattice constants of InP and AlGaAs, at any composition, are so far apart that epitaxially growth of the AlGaAs is impossible.

8b. The lattice constants of InP and GaP are so far apart that only less than a one percent solid solution in GaP in InP can be grown epitaxially on InP, and there are no known uses for such a low concentration solid solution of InGaP grown epitaxially on an InP substrate.

8c. Kikkawa provides no teaching suggesting substituting an InP substrate for the GaAs substrate of Passlack.

8d. Kikkawa describes a method and device structure for improving the contact resistance of p-type MISFET devices fabricated in GaAs-compatible materials systems. The materials of the layers that Kikkawa describes possess lattice constants similar to or slightly strained from GaAs. These materials all have lattice constants close enough to GaAs so that they can be grown epitaxially on a GaAs substrate.

8e. Kikkawa does not describe a compound semiconductor structure or transistor that would have any possibility of being grown epitaxially on an InP substrate. Depositing any of the structures described in the embodiments of Kikkawa on an InP substrate will result in the deposited layers being amorphous. This collection of amorphous layers would result in a transistor-like structure, in the sense that its macroscopic shape would look like a transistor, but that transistor-like structure would not function as a transistor. Thus, InP could not be substituted for the GaAs substrate for any embodiment disclosed in Kikkawa.

8f. Kikkawa does not facially suggest use of an InP substrate. Instead, he states that:

In the present embodiment, the material of the channel layer 54 acting also as the etching stopper is not limited to InGaAs but other materials such as InGaAsP or InGaP may also be used. Further, one may use InP for the substrate 51 in place of GaAs. The barrier layer 55, in turn, may be formed of GaAsSb or

AlGaAsSb. [Column 16 lines 5-10; emphasis added.]

8g. In context, and based upon that fact that neither AlGaAs nor InGaP lattice matches to InP, Kikkawa is suggesting a completely alternative structure to the GaAs substrate structure of the embodiment discussed up to column 16 line 5. That is, Kikkawa is suggesting using Sb based layers on InP as opposed to AlGaAs or InGaP layers. This is because (1) certain compositions of the Sb based quaternary's noted by Kikkawa, which are GaAsSb or AlGaAsSb, do lattice match to InP because they have similar enough lattice constant to InP and (2) because that no substantial composition of Sb in GaAsSb can lattice match to a GaAs substrate. The fact that a GaAsSb composition can lattice match to InP is confirmed by Fig. 2 of Vurgaftman et al, "Band Parameters for III-V Semiconductors and Their Alloys", J. Appl. Phys. PP 5816-5875 (June 1, 2001). Figure 2 shows a line connecting GaAs to GaSb indicating the existence of GaAsSb solid solution. That solid solution contains compositions having the same lattice constant as InP, as indicated by the fact that the line crosses on the x axis the lattice constant value for InP and therefore enabling lattice matching to InP. The fact that no substantial composition of Sb in a layer of GaAsSb will lattice match to GaAs is apparent from the relatively large lattice constant differences of GaAs and GaSb. Therefore, the only reasonable inference to draw from Kikkawa's reference to InP in combination with Sb based semiconductors is that a total replacement of all layers with InP and Sb based materials instead of merely replacing the GaAs substrate with InP. For all of these reasons, the examiner's interpretation of the teachings of Kikkawa are incorrect. Kikkawa does not suggest that GaAs and InP are equivalent or that they can be substituted for one another.

8h. Neither Passlack nor Kikkawa suggest substituting an InP substrate for the GaAs substrate of Passlack. Moreover, such a substitution would result in a non-functional device since (1) AlGaAs cannot be grown epitaxially on InP and (2) InGaP cannot (to an extent that could provide any useful properties) be grown epitaxially on InP.

9. Second, Passlack's stoichiometric Ga₂O₃ does not respond to the limitation defined in claims 36 and 38 of "a gate insulator structure." The first paragraph of the section of the specification of this application describing my invention defines the "gate insulator structure" recited in claims 36 and 38 as both electrically insulating and comprising at least two layers. That paragraph states in part:

The present invention provides, among other things, a self aligned enhancement mode metal-oxide-compound semiconductor FET. The FET includes a gallium oxygen insulating structure that is composed of at least two distinct layers. The first layer is most preferably more than 10 angstroms thick but less than 25 angstroms in thickness and composed substantially of gallium oxygen compounds including but not limited to stoichiometric Ga₂O₃ and Ga₂O, and possibly a lesser fraction of other gallium oxygen compounds. The upper insulating layer in the gallium oxide insulating structure is composed of an insulator that does not intermix with the underlying gallium oxygen insulating structure. This upper layer must possess excellent insulating qualities, and is most typically composed of gallium oxygen and a third rare earth element that together form a ternary insulating material. Therefore the entire gallium oxide rare earth gate insulator structure is composed of at least two layers and may contain a third

intermediate graded layers that consists of a mixture of the upper insulating material and the gallium oxygen compounds that compose the initial layer.

10. Please note that I wrote the specification without advise of counsel, which explains in part the reference to two layers as "first layer" and "upper insulating layer" to the extent that that lack of clarity and any other descriptions that lack complete clarity cause the panel any confusion.

11. The specification contains specific references to "gate insulator structure" or the equivalent "gate insulating structure" all of which are consistent with a multi layer structure that is insulating to the extent necessary to form a useful gate insulator. See the recitations:

A refractory metal gate electrode is preferably positioned on the upper surface of the gate insulator structure layer. [Page 5 lines 10-12.]

Together the lower gallium oxide compound layer and the second insulating layer form a gallium oxide gate insulating structure. [Abstract.]

The gallium oxide gate insulating structure and underlying compound semiconductor gallium arsenide layer (15) meet at an atomically abrupt interface at the surface of with the compound semiconductor wafer structure (14). [Abstract.]

12. Third, the Passlack patent does not disclose a gate insulator. The teachings of the Passlack patent do not enable one skilled in the art to form a structure containing a commercially useful device because the conductivity of the *stoichiometric Ga₂O₃ gate oxide layer* taught by Passlack is too high to be useful. The Passlack patent does not teach one of ordinary skill in the art this fact, and the Passlack patent does not teach one of ordinary skill in the art how to make a gate insulating structure having low enough conductivity to be useful. See book chapter 12 discussed above, wherein Passlack's own data shows that Ga₂O₃, per se, on GaAs is not useful.

13. In the context of the field of technology of this application, "complementary" means p and n type devices.

14. I swear under penalty of perjury that the foregoing is true and correct.

4/28/2003
DATE

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